Appendix A
Statement of Work
June 19, 2003
"University Research and Development (R&D) for Future Generation Solar Electric Technologies"

Introduction

The National Renewable Energy Laboratory (NREL), invites your submission of a response for a research project, entitled *University Research and Development (R&D) for Future-Generation Solar Electric Technologies,* in accordance with the requirements and conditions set forth in this document.

Background

In 1998, the U.S. Department of Energy (DOE) invited U.S. universities to submit proposals under the *University Research and Development (R&D) for Future Generation PV Technologies* solicitation. Through a rigorous selection process to identify sound research performed by highly capable researchers, the top 18 proposals of 72 submitted were funded in 1999 for 3 years. The Future Generation work brought 14 new principal investigators into the DOE Solar Energy Technologies Program. These projects were completed in 2002.

In the spirit of this earlier set of projects, this solicitation requests responses from the 18 Future Generation principal investigators and any university having an internationally recognized core of research strengths appropriate to tackling the technical challenges of Third-Generation Solar Electric Technologies. The Centre for Third-Generation Photovoltaics at Australia's University of New South Wales characterizes these technologies as having the *potential* for extremely high efficiencies, above 60%, and very low cost, below $100/square meter. First-generation technologies, those based on crystalline-silicon wafers, constitute the bulk of today's product in international photovoltaic markets. However, silicon wafers are limited in how much their cost can be reduced because of the amount of material needed. Second-generation technologies involve thin films, often a hundred times thinner than silicon wafers, and therefore have the potential for much lower cost. Their module efficiencies, however, are much lower than those of first-generation technologies.

A research area with the potential for high impact is, therefore, *improved thin-film energy conversion through nonconventional photovoltaic approaches*. The conventional approach for improving efficiency has been the elimination of various recombination and degradation processes that limit single-junction solar cell efficiencies. The first nonconventional means for improving efficiency was the development of multijunction solar cells in the 1980s. In the case of III-V multijunction solar cells, their complexity

due to lattice matching constraints and substrate cost have resulted in expensive solar cells suitable for high-value markets such as satellites or concentrator photovoltaic systems. Other non-conventional, high-efficiency approaches include multijunction cells employing innovative techniques to overcome lattice matching constraints and multilevel cells such as quantum dot, quantum well, and intermediate level or impurity doping concepts. Other approaches could include hot carrier and thermophotonic concepts. Other innovative ideas for very high efficiency at low cost are invited. Any of these concepts could be applicable to concentrator or flat plate solar electric systems. All of these potential third-generation conversion processes are based on what seems to be an enormous window of opportunity in that the thermodynamic limit for the efficiency of conversion of sunlight to electricity is 60% or higher. The catch is that no one is sure of the best avenue for reaching such high efficiencies. Thus far, these concepts have all been approached in the context of the generation of electron-hole pairs in inorganic materials. Exploring other approaches could prove fruitful.

Recently, successes in organic lighting technologies suggest there is another set of third-generation, solar electric technologies based on organic semiconductors. These materials have potential for even lower cost, below $50/square meter, because they are typically ten times thinner than the second-generation thin films. Light absorbed in these materials generates bound electron-hole pairs called excitons. Based on the successes of organic light-emitting diodes, essentially the inverse technology of a solar cell, the research into these materials could also have high impact if their efficiency is increased by a factor of 10, to above 30%. Both multijunction and nonconventional high-efficiency approaches are relatively unexplored in the case of organic materials. Some of these approaches may also be important for inorganic/organic material combinations, for example, nanoparticles in polymer films.

Objectives

The technical objectives are to conduct exploratory research for the development of innovative, future-generation solar electric technologies, using inorganic, organic, or inorganic/organic material combinations, having the potential for much higher efficiency, above 60%, and much lower cost, below $100/square meter, than first- and second-generation photovoltaic technologies.

Scope of Interest

The *University R&D for Future-Generation Solar Electric Technologies* solicitation requests responses for the research and development of nonconventional approaches for achieving very high efficiency and low cost in solar electric technologies based on inorganic materials, organic materials, or organic/inorganic combinations.

ELECTRONIC REPORTING REQUIREMENTS FOR SUBCONTRACT REPORT DELIVERABLES:

As set forth in Department of Energy Order 241.1A, NREL is required to submit in an electronic format all scientific and technical information, including subcontract report deliverables intended for public distribution, to the DOE Office of Scientific and Technical Information (OSTI). In addition, it is NREL's intention to post subcontract report deliverables containing publicly available information (e.g. non-confidential, non-protected, non-proprietary information) for distribution on the NREL Intranet or the Internet.

The NREL Subcontract Administrator and the NREL Technical Monitor shall determine which report deliverables are appropriate for submission and shall identify such report deliverables in the subcontract Statement of Work (SOW). The NREL Subcontract Administrator or Associate shall ensure that both the "hard copy(ies)" and the electronic version(s) of such report deliverables, identified in the subcontract Statement of Work and delivered by the Subcontractor in accordance with this Article, are sent to NREL Publication Services for subsequent distribution to OSTI.

The Subcontractor shall provide the final approved version of report deliverables intended for public distribution as specified in the subcontract Statement of Work in accordance with the following electronic reporting requirements:

a. The Subcontractor shall submit all report deliverables intended for public distribution (including status, annual, or final reports) as electronic files, preferably with all graphics and images embedded within the document. As identified in the subcontract Statement of Work, the electronic files shall be submitted along with an accompanying hard (printed) copy(ies) of the report. Limited exceptions allowing some graphics and images to be submitted as hard copies only may be granted on a case-by-case basis. The exceptions process for graphics and images is described in Paragraph E below. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied in hard copy only.

b. All final approved version submissions shall be delivered to NREL on PC or MAC-formatted media (3.5 inch disks, Zip and Jaz cartridges, or CD-ROM). Files of 1 Mb or less can be sent via e-mail to the 1) NREL technical monitor, 2) the NREL Subcontract Administrator or Associate (as specified in the Statement of Work).

c. The preferred format is a single electronic file that includes all of the text, figures, illustrations, and high-resolution digital photographs (or photographs should be scanned and incorporated in the text). Acceptable file formats are:
   - Microsoft Word (v.6.0 or newer for PC or MAC)
   - WordPerfect (v.6.1 or newer for PC)

- Microsoft PowerPoint
- Microsoft Excel

d. If it is not possible to include all of the graphics and images (figures, illustrations, and photographs) in the same file as the text, NREL will accept the text in one of the above formats and the graphics and images as separate electronic graphic or image files*. The native files for any page layout formats submitted shall be supplied. The following software is supported on both Mac and PC platforms:

- QuarkXPress (.qxd)
- Photoshop (.psd)
- Freehand (.fh)
- Framemaker (.fm)
- Pagemaker (.pm)
- Illustrator (.ai)
- Corel Draw (.cdr)
- Microsoft Publisher (.pub)

*The acceptable graphic or image file formats are: .eps, .tif, .gif, .jpg, .wpg, .wmf, .pct, .png, .bmp, .psd, .ai, .fh, .cdr. The preferred resolution for graphics or images is 150 to 300 dpi. Include all fonts that were used in creating the file.

e. In the rare case that the graphics or images cannot be supplied electronically, either incorporated within the text or as a separate electronic file, original hard copies will be accepted. The Subcontractor shall obtain prior approval from the Subcontract Administrator before submitting graphics or images in hard copies. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied in hard copy only.

f. For all calculations in support of subcontract reports that are conducted in ASPEN+, an electronic copy of INPUT, REPORT and BACKUP (if Model Manager is used) must be submitted with all reports. Additionally, if costing or sizing calculations are conducted in a spreadsheet [no process calculations (heat and material balances) in spreadsheet format are permitted], a copy of the fully documented MS Excel file shall be supplied. Note that vendor quotes and other non-original material can be supplied in hard copy.

g. A fully executed release shall be supplied to NREL with all photographs, regardless of whether such photographs are delivered to NREL electronically or in hard copy. Such release shall certify that the National Renewable Energy Laboratory and the United States Government is granted a non-exclusive, paid-up, irrevocable, worldwide license to publish such photographs in any medium or reproduce such photographs or allow others to do so for United States Government purposes.

h. The Subcontractor may contact NREL Publication Services at (303) 275-3644 with questions regarding technical guidance concerning the submission of subcontract report deliverables as electronic files or exceptions to electronic files for graphics and images.

The submitted reports shall be sent to each the following addresses:

National Renewable Energy Laboratory
Attn: (Subcontract Associate)
Program Office
1617 Cole Boulevard
Golden, CO 80401

National Renewable Energy Laboratory
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1617 Cole Blvd.
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